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The effect of a stimulus suffix on short-term auditory memory in preschoolers.

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University of Massachusetts Amherst

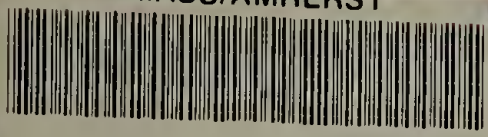
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The Effect of a Stimulus Suffix on Short-Term
Auditory Memory in Preschoolers

A Thesis Presented

by

Teresa Daly

Submitted to the Graduate School of the
University of Massachusetts in partial fulfillment
of the requirements for the degree of

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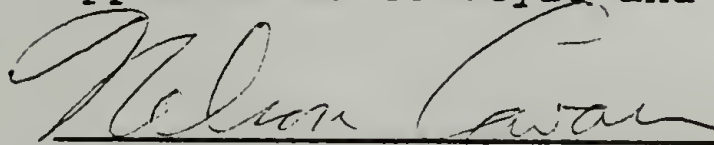
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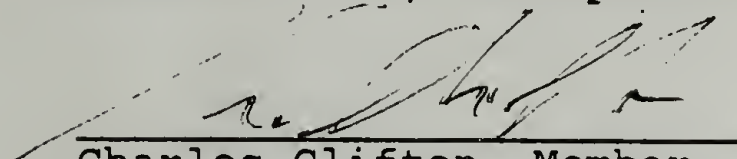
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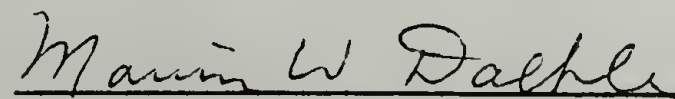
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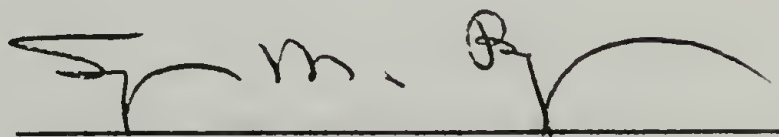
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ABSTRACT

Research investigating the duration and qualitative aspects of auditory short-term memory in young children has been long overlooked. Theoretical and practical benefits of such research may be great: it will provide information which will be of use to cognitive development researchers and educators alike. In this experiment, the duration of short-term auditory memory was assessed in 4-year olds. In addition, the sensitivity of children's auditory memory was evaluated by the use of a stimulus suffix procedure. Children were required to remember four-word lists over 10- and 20-second delay periods. The delay period was followed by one of three suffixes varying in acoustic similarity to the list-presentation voice: the same voice as the list, a different voice, or a control tone. Percent correct picture selection was analyzed for delay and suffix effects.

Auditory short-term memory at age 4 was useful for recall up to 20 seconds after list presentation. Memory was most negatively affected by the same-voice suffix. The effect of the tone suffix was significantly less than the effect of the same-voice suffix. Results suggest that preschoolers' short-term auditory memory behaves in ways very similar to adult short-term auditory memory.

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CHAPTER I

INTRODUCTION

Research exploring the temporal course and developmental characteristics of auditory memory in young children has been largely neglected. The possible practical as well as theoretical benefits of such research are great: on the practical side, for example, research on early reading experience has repeatedly shown that the proficiency of beginning readers is related to their ability to retain and compare phonological input (Bradley & Bryant, 1983). Thus, understanding the properties of children's auditory memory limits should eventually be of use to educational psychologists and teachers who are concerned with teaching reading to young children. The importance of auditory memory in language learning and reading is clear for both normal (Kucjaz, 1979; Morais, Cary, Alegria & Bertelson, 1979) and language impaired (Tallal, Stark, Kallman & Mellits, 1981) children. Greater knowledge of auditory memory should also prove important to those studying learning disabilities (Seigel & Linder, 1984).

In addition, such research could have theoretical importance. Young children do not use adult memory strategies (Flavell, Beach & Chinsky, 1966; Kail & Hagen, 1981). Therefore, another benefit of research on children's short-term auditory memory is its implications for adult

memory models: it can help define structural components of short-term memory relatively free of strategy interference (Cowan & Kielbasa, in press).

This introduction will outline the current understanding of auditory short-term memory in children, first by examining our knowledge of adult short-term memory, then by analyzing available research on children's short-term auditory memory, as well as summarizing relevant methodologies used in the investigation of other aspects of short-term memory in children. The purpose of the current study is to further clarify the duration and sensitivity of auditory short-term memory in preschoolers, and a description of the specific goals and focus of this experiment can be found at the end of this chapter.

Adult Studies of Auditory Memory

Models of auditory memory. A substantial number of studies have been conducted to elucidate the course of auditory short-term memory in adults (see Crowder, 1983 and Cowan, 1984 for reviews). The concept of an echoic, or short-term auditory store has become popular in the last 20 years. In this store, which represents the earliest stage of information processing, information remains unanalyzed, and retains the basic properties of the auditory input. Such a system could be important for understanding complex sentences and making use of intonational cues which sometimes signal the intent of the speaker only at the very

end of the speech string. Although such information is unanalyzed, it can be scanned and identified for covert rehearsal (Crowder, 1976). The echoic store eventually becomes unavailable, lost by either displacement, erasure or decay.

Crowder's experimental work led him to hypothesize that echoic memory represented a precategorical acoustic storage (PAS) system (Crowder & Morton, 1969). He envisioned this store as retaining properties of the sensory channel, and being influenced by both the closeness in time and channel of the input, as well as the input's speed and strength of activation of long-term memory associations. Thus, echoic memory for any given stimulus will be affected both by the number and physical nature of other stimuli impinging on the store, and by the associations between that stimulus and others in long-term memory.

Since all auditory information occurs across time, the existence of a short-term auditory store seems logical. Crowder and Morton (1969) saw this storage system as limited in both size and duration. Crowder (1976) addressed some of the possible avenues of information loss in echoic memory. He believed that each input into auditory short-term memory masked previous items to some degree. Therefore, the last item auditorily presented, has the purest memory trace. Crowder hypothesized that this phenomenon accounted in part

for the large recency effect seen in auditory but not visual memory tasks. He believed that rehearsal always occurs between the end of the last list item and the beginning of recall. Thus, the last list items benefited from both rehearsal and the echoic trace, leading to a recency effect.

Baddeley proposed a similar system of short-term memory. His three-component memory system consists of a sensory storage system (a visual-spatial scratchpad for storing visual information, an articulatory loop for auditory information), and a central executive for actively processing information in memory (Baddeley, 1981). The sensory storage system temporarily holds a trace or motor program necessary for producing that trace until it can be recoded verbally (if it is visual in nature) or acted upon by the central executive. Recent evidence suggests the non-auditory component of short-term memory is quite small (Zhang & Simon, 1985), and quickly becomes unavailable if not recoded in another form.

Both models posit a sensory-perceptual memory trace that retains some properties of the sensory channel. In addition, both Crowder and Morton (1969) and Baddeley (1981) propose that this auditory store is temporally limited. A simplification of these two models can be found in Figure 1.

The notion of a time constraint on short-term memory is a fairly common theme in the literature, and one that seems quite plausible. However, it must be asked if this time

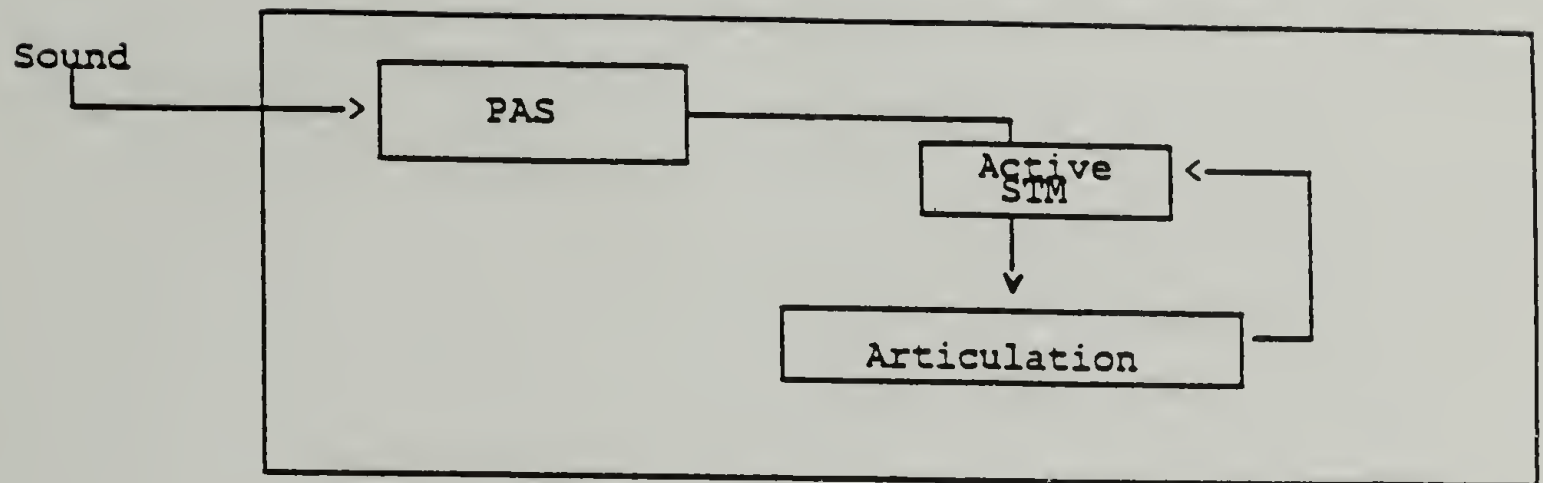


Figure 1. Illustration of PAS and its relation to short term memory.

constraint changes with development. If the duration of short-term auditory memory is biologically determined, then maturation might lead to changes in the temporal limits. However, Baddeley found that digit span length could be predicted by the number of words an individual was able to read aloud in 2 seconds. This finding held across the age span, and led to his hypothesis that the articulatory loop is temporally limited. Recent work has cast doubt on the purely temporally-based explanations of short-term memory limits and differences seen between adult and child memory limits (Case, Kurland & Goldberg, 1982; Chi, 1976; Stigler, Lee & Stevenson, in press). In addition, the exact duration of short-term auditory memory has been disputed (Crowder, 1983; Crowder & Morton, 1969; Watkins & Todres, 1980, Watkins and Watkins, 1980).

Adult methodologies. While there is controversy in the field of short-term memory, the existence of an auditory specific short-term memory is widely accepted, as are the methodologies used to evaluate it. Although a number of approaches to investigate the nature of this store have been used (Darwin, Turvey & Crowder, 1972; Massaro, 1972; Treisman, 1964), one of the most prevalent techniques is the stimulus suffix paradigm (Dallet, 1965; Crowder & Morton, 1969). This procedure requires a subject to serially recall an auditorily presented list of items to which an additional

item, which is not to be recalled, has been appended.

Typically, the suffix paradigm includes both a control and a suffix condition. The control usually consists of either a no-suffix condition or a non-speech suffix (such as a tone or a click) placed at the end of the list. In the suffix condition, a speech suffix is presented at the end of the list. The subject is familiarized with the suffix before the list is presented, and is instructed to begin recall immediately after the suffix is heard. For example, the subject might hear an eight-item list followed by the suffix "Go" (e.g., "Dog, Tree, Egg, Hat, Farm, Box, Gate, Sled, Go"). He would then write in the exact same order, to the best of his memory, dog, tree, egg, hat, farm, box, gate, sled on a prepared response sheet.

Experiments using the suffix paradigm. Although it makes sense that the subject would ignore the additional item, results indicate that the addition of such an item substantially reduces accuracy of recall for the last serial position when the suffix follows the final item within several seconds (Crowder, 1969, Crowder & Morton, 1969). The interference caused by the suffix reduces the recency effect observed in most serial position curves. Moreover, for adults, a speech suffix is most damaging to memory when it is presented in the same voice as the list (Morton, Crowder & Prussin, 1971), suggesting there is an acoustic trace or sensory-based memory for these last few items.

Crowder (1978) argued that the suffix effect reflects the auditory nature of short-term memory, providing support for his PAS model. He suggested that non-speech suffixes allow the subject to retain the speech-specific auditory information of the list, which can be used to aid in rehearsal and other retention strategies before the report phase of the experiment. This would lead to the typically observed recency portion of the serial position curve for serially presented memory tasks. When a speech suffix follows the list, however, the physical similarity of this input to the original list items interferes with the echoic trace, which especially affects recall for those items immediately before the suffix.

There has been experimental support for this interpretation. Work by Morton, Crowder and Prussin (1971) has shown that neither the meaning nor the category membership of the suffix item changes the suffix effect. Thus, the word "fan" would have the same effect on a list of concrete nouns as it would on a list of numbers. Similarly, the word "zero" would have no greater effect on a list of numbers than would the word "fan." In addition, the effect of nonsense syllables was no different from the effect of real words or unintelligible words (e.g., "uh") in this study. No suffix effect was obtained when loud (90dB) or soft (80dB) white noise was used as a suffix, whereas both

loud and soft speech suffixes produced the typical suffix effect.

However, Greenberg and Engle (1983) have indicated that the suffix effect may index two memory components. The effect of a suffix on preterminal list positions is influenced by practice and presentation rate, suggesting an attentional mechanism. In contrast, the effect of a suffix on memory for the final serial position is not affected by practice or presentation rate, suggesting a structural explanation. Thus, the final serial position provides a good index of the auditory component of memory, as Crowder suggested, but the suffix effect itself is more complex than Crowder initially believed.

These observations provide converging support for Crowder's model of a PAS system. If cognitive processing were occurring between list presentation and recall, one would expect a suffix from the same category as list items to have a greater effect on recall than a suffix from a different category. The fact that this is not the case would seem to indicate that the items are held in a precategorical store, as Crowder suggests. However, Crowder's early contention that this store does not extend past two or three seconds (Crowder, 1971) has come under fire. Using a delay paradigm, Watkins and Watkins (1980) found evidence of an acoustic store that extended for up to 20 seconds. This and other recent research has led Crowder

to modify his explanation of the temporal course of auditory memory (Crowder, 1983).

Watkins and Todres (1980) studied the time course of auditory memory by applying additional modifications to the suffix paradigm. They analyzed memory over 5 delays ranging from 2 to 20 seconds in length. To assure the subjects were not encoding the list in some suffix-resistant memory over these delays, Watkins and Todres introduced a series of sums to be completed during the delay interval. This silent distractor task was implemented to prevent subjects from using cognitive retention strategies that may have obscured findings of previous studies that used unfilled delays in assessing auditory short-term memory. At all delays, Watkins and Todres found significant suffix effects. The suffix effect diminished as delay length increased, but was still evident at 20 seconds. Recall at 20 seconds showed a robust suffix effect in the arithmetic distraction group and a small effect in a control group with an unfilled delay. Balota and Duchek (in press) have also studied the suffix effect at longer delays by replicating Morton, Crowder and Prussin's (1971) experiment evaluating the effect of acoustic similarity of suffix to list items. Their results indicate that the acoustic similarity of a suffix to its list influences auditory memory for that list for more than 10 seconds, although the effect of an acoustically similar suffix is not distinguishable from the effect of other

suffixes by 20 seconds.

Parkinson (1978) suggests that task demands may have a great effect on the outcome of suffix experiments. Using a suffix paradigm with a forced-choice recognition response phase and adult subjects, Parkinson found he did not obtain a suffix effect, while such an effect was readily evident when a recall report phase was employed.

Parkinson's results may suggest that the suffix paradigm might not tap the structural components of auditory memory, but rather some combination of structural and strategic memory. On the other hand, Parkinson's findings may be attributed to differences in retrieval under recall and recognition conditions. Or, it may be possible that items held for recall are encoded differently than those stored for recognition. If items in the recognition set provide partial report cues for auditory memory, then the implication is that an auditory trace may last much longer than shown in most suffix experiments. It may be that the trace remains but becomes less easily accessible for recall without retrieval aids as time passes.

The implications of these studies for general memory models and for models of memory development are interesting. If an auditory store which could exist in the absence of strategy use is available to adults, more time to actively consider strategy selection would be available, which might

account for advantages seen when adult and child short-term memory is compared. On the other hand, a short-term auditory store that lasts for several seconds in the absence of strategy use would be very beneficial for developing children, who may require more time to make associations between items currently being processed and items in long term memory (Dempster, 1983).

Auditory Memory in Children

The study of auditory memory in preschool children differs from adult study in two major respects. First, little is known about auditory memory and its duration in young children; the few studies that have been done with children have either used older children or not addressed the question of the duration of auditory memory. Second, new methodologies are necessary. Methods used in adult studies are not directly applicable to preschool children.

Studies of auditory memory in children. The study of auditory memory development has been addressed through several methodologies. Using an auditory acuity task, Irwin, Ball, Kay, Stillman and Rosser (1985) found that auditory acuity increased in children between ages 6 and 12. The children were required to detect gaps in a broadband noise, and achieved adult levels by age 11. While this study provides interesting and valuable information, it tells little about the qualitative nature of children's short-term auditory store. Davis and McCroskey (1980) used

a tone fusion technique to evaluate the duration of short-term auditory store in children from age 3 to 11. Their results indicated that the duration of such a sensory store might actually diminish across that age range. However, the nature of the task used in this study was somewhat abstract, and may have provided different information than experiments using more ecologically valid stimuli.

Several studies have used older children in studying auditory short term memory. Frank and Rabinovitch (1974) showed that suffix procedures could be modified for use with school children. The younger children in their study were more affected by a suffix than were the older group; however, Engle, Fidler and Reynolds (1981) took the suffix paradigm one step further by showing that older children's performance could be brought down to the level of younger children if the rate of presentation of list items was increased enough to prevent rehearsal. Both these experiments used immediate suffix conditions and elementary school children and relied on unaided recall procedures.

Dempster and Rohwer (1983) used school children to developmentally assess the modality effect in free recall. Their results showed an increase in the recency effect with age; however, this increase was not specific only to the auditory modality, as it had been in most adult studies.

Methodological concerns. Naturally, school children

are easily accessible as well as easier to work with than preschoolers. However, these children may have additional ways of encoding auditorily presented items, and some of these methods of encoding may be suffix resistant. For example, these children may also use an orthographic code. And, as realized by Frank and Rabinovitch (1974) and Engle et al. (1981), older school children are more likely to use strategies to help them retain information. These possibilities presented problems that are not likely to be found in the preschool population. Thus, many potential confounds are eliminated when preschool children are used in studies of auditory short-term memory.

It is easy to see that the methods used in adult studies as well as methods used in some studies using school children are not directly applicable to preschool children. Most arithmetic tasks would be beyond their ability. Moreover, since preschoolers are largely preliterate, the typical suffix paradigm, which relies on written recall, cannot be used. In addition, any verbal production would interfere with the auditory store; therefore, using a verbal response phase would not be acceptable. In order to investigate the duration of auditory memory, a silent delay period is required. It is difficult to maintain quiet attention in preschool children, as any mother will attest. These complications may have caused many researchers working in the area of auditory memory to avoid questions

surrounding the nature of this memory in children.

Cowan and Kielbasa (in press) have studied the limits of short-term auditory memory in four-year olds by using a delayed suffix procedure. The four-year-old age group was chosen for several reasons. First, the four-year-old population has a sufficient vocabulary and attention span to allow for an adequate number of trials to draw conclusions about auditory phenomena. Second, these children are also able to understand simple standardized instructions. Finally, this age group shows no evidence of overt or covert rehearsal, although four-year olds sometimes shown behavior that may be a precursor to rehearsal strategies (Baker-Ward, Ornstein & Holden, 1984).

Conscious of these points, and inspired by Flavell, Beach and Chinsky (1966), Cowan and Kielbasa (in press) developed a new procedure especially for use in studying auditory memory in this age group. Flavell et al. had used a delay procedure in assessing picture recognition in kindergarten and elementary school children. The clever design of their study involved the use of a "space helmet" visor which the children were required to wear during the delay interval. The visor prevented them from viewing the pictures during the delay and provided them with an amusement at the same time. Unfortunately, since Flavell et al were investigating visual memory and did not control

noise during the delay interval, generalizing their methodology directly to auditory memory studies would be impossible: the children's output would most likely interfere with auditory memory for the recently presented list. Nevertheless, their data strongly suggested that, despite children's limited attention spans, delay procedures are appropriate for studying children's memory if care is taken to make the task interesting in an age-appropriate way.

Preschoolers cannot write during a report phase or add even simple sums graphically during a delay interval as in the Watkins and Todres study (1980). However, a silent delay is necessary to study the temporal limits of auditory memory. During the delay, Cowan and Kielbasa (in press) provided an alternative distractor task which was both demanding and silent. The children first listened to a list of nonsense words which they were required to remember. A gesture imitation task involving some fine motor movements most preschoolers find challenging and enjoyable (e.g., wiggling both thumbs, touching nose with index finger) was used to keep the children both silent and occupied during the delay interval. Thus, the delay interval was without any auditory or verbal input, and additionally prevented any rehearsal attempts by these children. After a variable delay, children were required to select pictures of real words whose names rhymed with list items. The results of

this experiment showed that children are able to retain auditory information for over ten seconds, supporting the findings of Watkins and Watkins (1980) and Watkins and Todres (1980). In addition, these results indicated that children are able to retain auditory information for several seconds in the absence of semantic information, and that these children were remembering the words rather than merely the pictures.

Cowan and Daly (manuscript in preparation) hypothesized that children might retain some gross acoustic features of a word but be unable to identify the word exactly. By using stimuli sets with phonologically similar foils, the accuracy of this hypothesis may be tested. Retention of acoustic features would lead to a larger number of rhyming errors than non-rhyming errors. In addition, using phonologically similar foils adds an element of difficulty to the task, which the researchers felt advisable in light of Parkinson's (1978) findings.

Using such stimulus sets with four-year olds, Cowan and Daly studied auditory memory over 2-, 10-, and 20-second delays. After each delay, children were required to indicate list items by pointing to them in an array of pictures, some of which had names which rhymed with list items. The high percentage of correct answers and wrong answers which were phonologically similar to the correct

answer observed in this study suggested that auditory memory lasts over 10 seconds, and is sensitive to phonological similarity even in a preschool population. Follow-up work using only pictures with dual labels as list items indicated that children were remembering the words themselves rather than just the pictures. This work, combined with the Cowan and Kielbasa study (in press), indicates that preschoolers are able to retain auditory information for several seconds, and that the retrieval of this information may be influenced by phonological aspects of the stimuli.

Goals of this Research

The duration of auditory memory in young children requires further confirmation. In addition, questions about the effect of acoustic similarity on children's auditory memory still need to be answered. Using lists comprised only of rhyming words has led to conflicting results (Alegria & Pignot, 1979; Conrad, 1971; Hulme, 1984) when young children are the subjects. Using lists of phonologically dissimilar (non-rhyming) words with phonologically similar (rhyming) foils among a recognition set (Cowan & Daly, manuscript in preparation; Cowan & Kielbasa, in press) has provided interesting and useful information about children's sensitivity to acoustic similarity.

Issues of auditory short-term memory in children can be addressed through modification of the various paradigms used

in previous studies. In addition, it remains to be seen if children's auditory memory behaves in the same way as adults' when presented with similar tasks. Morton, Crowder and Prussin (1971) showed a suffix had differential effects based on its acoustic similarity to the presentation list for adults. Balota and Duchek (in press) have found the same effect when the suffix is delayed up to 20 seconds. This effect has not been established in young children who do not use rehearsal, and therefore, could not transform the auditory information (through strategy use) into some form of suffix-resistant memory in the course of 20 seconds. Thus, the existence of a 20-second auditory-based store in young children would provide support for the concept of an auditory storage system like Crowder's PAS (1971; Crowder & Morton, 1969).

In this experiment, a stimulus set designed especially for use with preschoolers was used with a delayed suffix procedure. The stimuli were carefully chosen to permit responses that would be of use in distinguishing the level of auditory memory present at each delay length and for each suffix type. All lists consisted of phonologically dissimilar (non-rhyming) words. On half the trials, foils that were phonologically similar to (rhymed with) list items were among the recognition set. For the other half of the trials, only phonologically dissimilar (non-rhyming) foils

were in the recognition set. This manipulation both made the task more demanding for subjects and provided an additional index of auditory memory. The delayed suffix approach was selected to allow study of several components of preschoolers' auditory memory simultaneously. More specifically, we asked the following: First, what is the duration of auditory short-term memory in four-year olds? Second, how does a suffix affect this auditory memory? Finally, to what extent is auditory short-term memory at age four differentially sensitive to the acoustic similarity of a suffix and/or the phonological similarity of a foil?

C H A P T E R I I

M E T H O D

Subjects

The subjects were 48 normal English-speaking preschool children between the ages of 4 years, 4 months and 4 years, 8 months ($M=4$ yrs, 6 mo.,; $SD=.98$ mo.) whose names were obtained from the Springfield, Massachusetts records of birth. This age range was selected based on previous research using this type of paradigm (Cowan and Daly, manuscript in preparation) which indicated that children 4 years, 3 months and younger had difficulty understanding the task requirements and performed too close to chance levels (less than 40% correct) to produce informative results, while children older than 4 years, 8 months often had experience in reading and spelling instruction to prepare them for elementary school which could provide them with additional codes for memory. Data were obtained from an additional 9 children who were excluded from the final sample (3 because of experimenter error, 3 because of talking during the test trial delay intervals, 2 who performed too close to chance and one who did not complete the session). Parents were contacted first by letter and later by telephone and brought their child to the Child Study Center in Springfield. Children of bilingual homes in which the primary language was not English were not included

in the study. Each child took home the sticker picture he or she made during the session and received a children's book for participating.

Materials

The test materials consisted of 42 plastic-covered photo album sheets (36 test, 6 practice) each containing three 3x5 color drawings mounted vertically on the page. A sample of these pages may be found in Appendix A. List items appeared with equal frequency at the top (T), middle (M), and bottom (B) of the page. Four pages were used on each trial, and each page contained one list item and two foils. List items and foils may be found in Appendix B. Previous research using these drawings showed that children were both able to correctly name each picture used as a list item without prompting and to recognize all foils. The few confusions shown by children found in spontaneous naming conditions (e.g., dolphin for seal, ladder for track, feathers or fan for shell, snake for worm) were all for foil items. Proper identification of these foil items was easily obtained by asking, "Can you find a (word)?" This was seldom necessary, as confusions rarely occurred; in fact, a study that required children to name all pictures in this stimulus set showed that spontaneously generated labels were the same labels as intended by the experimenter in an overwhelming majority of the cases. In addition, there were no picture preferences seen in pilot work with these

stimuli.

A cassette tape recorder was used to standardize the presentation of the lists. Connected to the tape recorder was a brightly colored toggle box showing a fuzzy monster with a big nose (the toggle). It was hypothesized that children this age might be disturbed by a voice in absence of a viable source. This box was included to relieve some of the potential confusion by providing a "source" for the voice. Children were told that they could make the monster talk by pushing his nose up. The recorder was actually controlled from a hidden remote switch operated by the experimenter.

Design

A 3 (suffix type) x 2 (delay) x 2 (phonological similarity) x 4 (serial position) design was employed. Thus, each subject received 12 tape-recorded trials of four-word lists presented in a female voice, followed by a suffix after a delay. All subjects received the same word-lists in the same order. Half the trials employed a 10 second delay, the others, a 20 second delay. These delay intervals were suggested by previous data (Cowan and Kielbasa, in press) which indicated that children's memory decayed rapidly between 10 and 20 seconds. For each delay condition, a tone was used as a suffix on 2 trials, a different voice (male voice) on 2 trials, and the same voice (female) on the

remaining 2 trials. Finally, on one of the 2 trials of each suffix type subjects received a list containing some phonologically similar (Rhyming) foils among the pictures in the recognition set, and on the other trial, they received a list with phonologically dissimilar (Non-rhyming) foils. On half the trials, the subjects were probed for recall in the order in which the words had been presented (forward order). On the remaining trials they were probed for recall in reverse (backward order).

Counterbalancing procedures are summarized in Appendix C. Order of suffix presentation was determined by a Latin Square (Tone, Same-voice, Different-voice (TSD); Same, Different, Tone (SDT); Different, Tone, Same (DTS)), with 16 subjects in each order condition. Order of delay presentation (10 s then 20 s, or 20 s then 10 s) was alternated with every second subject. Half the subjects received forward probe orders during the first six trials and backward probe orders during the last six trials, while the other subjects received backward probes in the first half and forward probes during the last six trials. In addition, the first 24 subjects received lists with phonologically similar (R) foils on odd trials and lists with phonologically dissimilar (N) foils on even trials during the first half of the session and the reverse order for the second half (i.e., RNRNRN/NRNRNR), while the second 24 subjects received phonologically dissimilar lists on odd

trials during the first half of the session (i.e., NRNRNR/RNRNRN).

Procedure

Each child was tested individually in a quiet room while parents observed through a one-way mirror or on a video monitor.

Familiarization Phase. A minimum of five practice trials were administered to introduce the child to the various components of the game (memory task, "Simon says" activity, tape recorder, probe order, earning stickers) and to build rapport. The test trials began when the child showed understanding of the game rules. After each trial, the child received a sticker and engaged in conversation with the experimenter. The number of stickers given per trial often had to be increased mid-game to maintain the appropriate level of motivation and interest during a rather long task. (The session took about 45 minutes.)

Test Phase. Each subject was assigned to one of 24 test conditions, which differed in order of probe presentation (forward and backward), order of delay presentation (10s and 20s), and order of suffix presentation (TSD, SDT, DTS). Each child was presented with the same word lists in the same order; only the order of delay and suffix conditions changed across children. Before each

trial, the child identified the pictures (both foils and list items). Four album pages were placed in front of the subject, and the experimenter asked the child to "find" and point to each object. After all 12 items had been "found," the cards were collected and put face down at the experimenter's side. The experimenter then told the child to "push the monster's nose up," and started the tape recorder. Each list began with the word "Ready?" followed by a 1 second pause before the four items. Items were presented at a rate of 1.8 per second. Coincident with the last word, the experimenter immediately began the "Simon says" activity with which the child had been familiarized during practice trials. In this variation of the game, the experimenter silently initiated a simple motor movement or combination of movements (e.g., hands on head, touch nose, finger movements) which the child imitated. The experimenter continued to introduce additional silent gestures to be copied at the rate of about 1 action per second until the suffix was heard. The album pages were then presented in the appropriate probe order immediately following the suffix offset. As the child pointed to a picture, the experimenter recorded the response with a check mark on a prepared response sheet, and the next album page was presented.

CHAPTER III

RESULTS AND DISCUSSION

The dependent measure in this experiment, correct picture selection, was analyzed in a 3 (suffix type) x 2 (delay) x 2 (phonological similarity) x 4 (serial position) analysis of variance. Significant effects included suffix type, $F(2,94) = 3.56$, $p < .05$, phonological similarity of foils, $F(1,47) = 15.04$, $p < .0005$, and list position, $F(3,141) = 2.57$, $p < .10$. Mean percentage correct responding for each variable is shown in Table 1.

As can be seen from the table, subjects averaged approximately 65% correct across all conditions--well above chance performance (33%). Performance was highest in the tone (control) suffix condition, while performance in the different-voice condition was better than performance in the same-voice condition, Suffix type $F(2,94) = 3.56$, $p = .03$. This pattern of results is consistent with the findings of adult studies (Morton, Crowder & Prussin, 1971; Balota & Duchek, in press). Although mean differences between suffix types are not as large as seen in most adult studies, the direction of result is the same; that is, the subjects were most affected by the suffix with the greatest acoustic similarity to the memory list (same-voice suffix), followed by any other speech suffix (different-voice suffix), and were least affected by a non-speech (tone) suffix.

Table 1
Mean Percentage Correct Picture Selection

Lists With Phonologically Similar Foils

<u>Delay</u>	<u>Suffix Type</u>			<u>Mean</u>
	<u>Same</u>	<u>Different</u>	<u>Tone</u>	
10 seconds	58.33	59.38	67.71	61.81
20 seconds	50.52	60.93	64.06	58.51
Mean	54.43	60.16	65.89	60.16

Lists with Phonologically Dissimilar Foils

<u>Delay</u>	<u>Suffix Type</u>			<u>Mean</u>
	<u>Same</u>	<u>Different</u>	<u>Tone</u>	
10 seconds	69.27	74.48	66.14	69.97
20 seconds	66.67	66.67	70.83	68.06
Mean	67.97	70.57	68.49	69.01

Bonferroni t -tests revealed a significant difference only between control (tone) and same-voice suffix, (T>S), $t(94) = 2.68$, $p < .05$. In contrast, previous adult studies that have used acoustic similarity of suffix as a variable have shown a significant difference between both control and voice suffixes and between same- and different-voice conditions, at least for short intervals (Morton, Crowder & Prussin, 1971; Balota & Duchek, in press). The lack of a voice-specific suffix effect is consistent with recent adult data at long delays (Balota and Duchek, in press). However, in the adult study, the same- and different-voice means fell right on top of each other in the 20 seconds delay condition, whereas the means- for same and different-voice suffixes in this experiment were more spread out.

Unfortunately, the difference between voice suffixes was not significant. The lack of statistical significance between voice suffixes may be explained in two ways. First, it may indicate that children are somewhat less sensitive to the properties of a suffix than are adults. There could be attentional reasons for this: perhaps any suffix is very distracting for children. In this case, differences between same- and different-voice suffixes or voice and control suffixes would not be expected. Alternatively, it may be that children are sensitive to gross differences in suffixes, but not to the more subtle differences involved in the same- and different-voice distinction. Neither of

these explanations seems very satisfying. First, the significant difference between control and same-voice conditions would eliminate the initial suggestion. Similarly, the lack of a significant difference between control and different-voice suffix would rule out the alternative suggestion. However, neither of these points precludes the possibility that children are more sensitive to a tone or non-speech suffix than are adults, and that such a suffix might not serve as a true control when used in experiments with children as subjects. It may be that a difference between control and different-voice suffix conditions was obscured by the absence of a true control situation. Nevertheless, this would not account for all the differences seen between comparisons of mean percent correct for suffix types in adults and children.

Perhaps a better explanation of the absence of significant differences for different-voice vs. control and different-voice vs. same-voice comparisons is methodological. Few studies have used delays as long as 10 seconds, and those that have (Balota & Duchek, in press) have had mixed results. Balota and Duchek found no difference between same- and different-voice suffixes at 20 seconds, but significant differences between control (tone) and either voice suffix at 20 seconds. More importantly, however, the suffix effect is usually not large in

magnitude, especially when compared across delays. Consequently, large numbers of trials are required to establish a reliable effect. The number of trials run in a typical adult suffix study is much greater than would be possible in child studies. For example, Balota and Duchek ran 72 trials in their experiment (in press), while Watkins and Todres (1980) ran over sixty trials per subject compared to the 12 run in this experiment. Since the observed pattern of results follows a logical order based on adult research and theory, it is possible that more trials would have resulted in significant differences in the tone vs. different-voice and same- vs. different-voice comparisons.

This pattern of results held for both delay intervals, although performance in the voice suffix conditions declined sharply between 10 and 20 seconds. The tone and different-voice suffix had the same effect at 10 seconds, but affected memory differently at 20 seconds, as is shown in Figure 2. This may suggest that for children, unlike adults, the potential effects of speech interference increase over the interval required to retain information.

Balota and Engle (1981) have indicated that the best measure of auditory short-term memory is seen in the final serial position of a list. For this reason, a separate analysis was performed on the 4th serial position responses only. Data from this position may also provide the best information about the suffix effect since the only

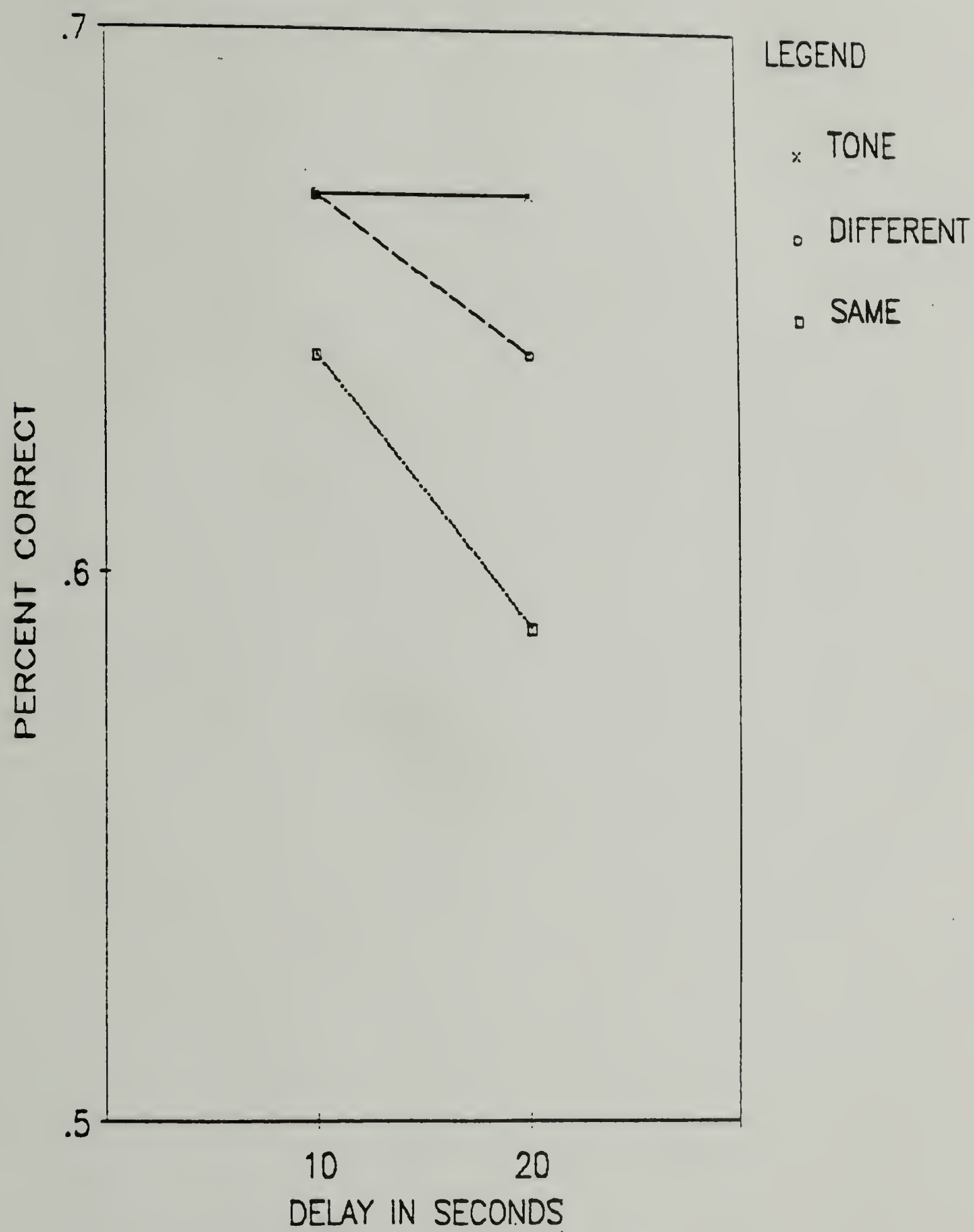


Figure 2. Mean percentage correct as a function of delay and suffix.

retroactive interference for this position is the suffix itself. Significant effects were suffix type, $F(2,94) = 2.67$, $p = .07$, and phonological similarity of foils, $F(1,47) = 5.28$, $p = .03$. There was an interaction between suffix and delay, $F(2,94) = 2.65$, $p = .08$. In this analysis, the difference between suffix types was larger; 71% of tone trials were correct, while the same was true of only 60% of same-voice trials, $t(94) = 2.70$, $p < .05$. Interestingly, in this serial position the mean for the different-voice suffix (68%) was higher than it was across serial position, and was much closer to the mean for the control, which may indicate that sounds that are very acoustically similar interfere more with auditory memory than less acoustically similar sounds. However, it may not be wise to accept this conclusion from the current data alone, as there was no suffix by serial position interaction in the main analysis.

No significant effect of delay was seen in this study, $F(1,47) = 1.17$, $p < .30$. While this weakens any statements made about the effects of the variables at different delays, it is possible that the absence of a delay effect is an artifact of the design. It may be that the main effect of delay is seen between 0 and 10 seconds. This study provides data for the course of memory over this interval. However, if it were the case that the main effect of delay occurs within the first ten seconds after list presentation, a small decline between 10 and 20 seconds would be expected

but might not be significant. This is in fact the observed result in this experiment, where the mean percent correct at 10 seconds was 66%, while at 20 seconds it had only declined to 63% correct. It should be noted that this is still considerably above chance (33%), indicating that short-term memory for speech sounds is present, although not perfect, at delays as long as 20 seconds.

There is another possible explanation for the lack of a delay effect. It may be that the suffixes themselves (including the tone) were so debilitating that they flattened the delay curve substantially. In this case, it would be predicted that the suffix effect would obscure the delay effect. For practical reasons, it was impossible to include a no-suffix (silent) control condition in this study. However, in previous studies using these stimuli without a suffix (Cowan and Daly, manuscript in preparation), the mean percentage correct at 10 seconds delay was 73%, while that 20 seconds was significantly lower (61%). The difference between these values is considerably larger than is observed in the current experiment. It should be noted that all trials in the Cowan and Daly study used phonologically similar foils, and thus, may have been more difficult to remember than the combination of phonologically similar and dissimilar foils used in this study. Nevertheless, it can be seen (Figure 3) that

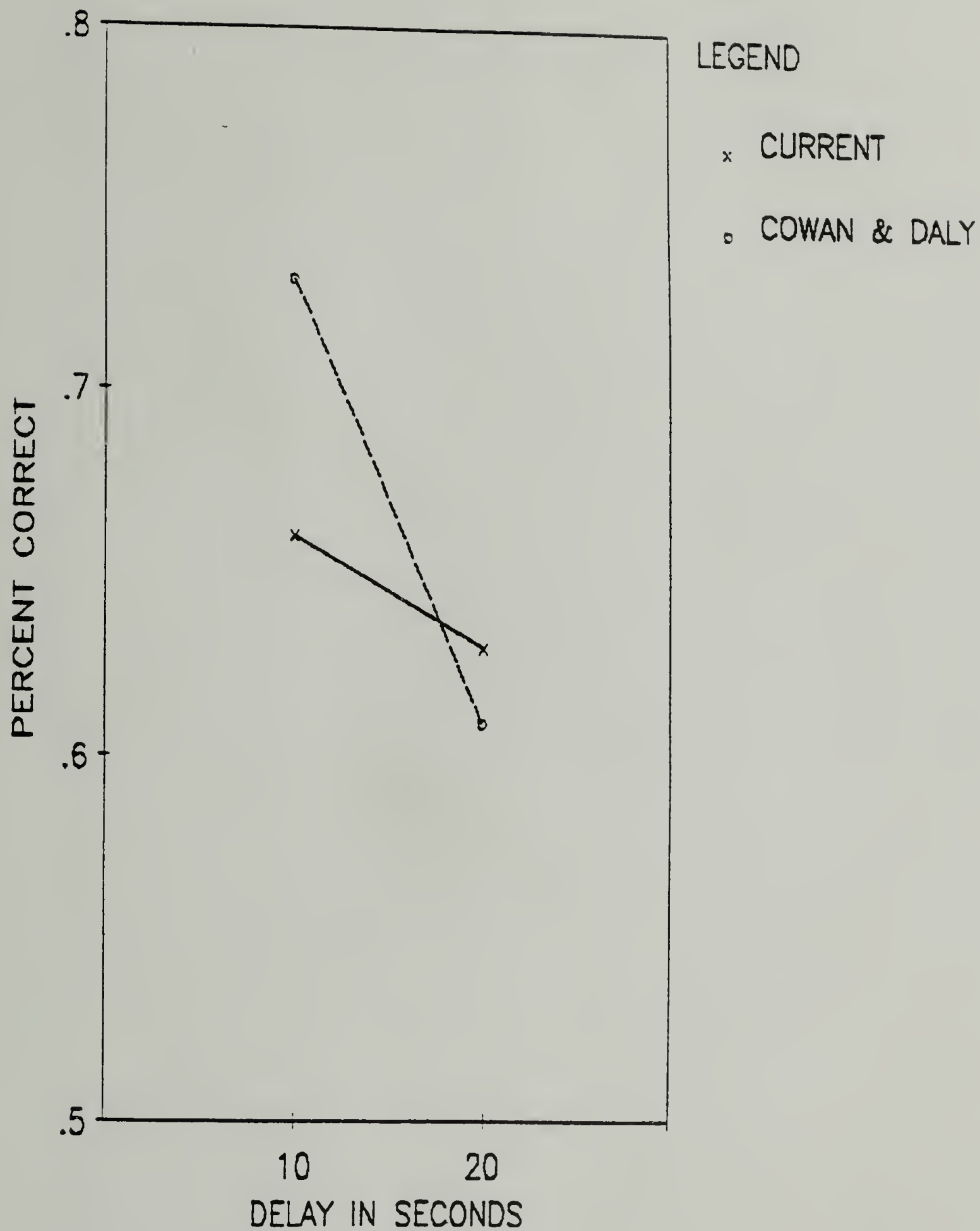


Figure 3. Comparison of mean percentage correct as a function of delay in the current study and a previous study using the same stimuli.

percentage correct at 20 seconds is about the same in both studies, but at 10 seconds there is a considerable difference. Thus, the explanation that delay effects were concealed by the more powerful suffix manipulation in this study seems plausible.

Finally, the absence of a delay effect is in itself interesting. One might expect this would mean that the effect of a suffix would be equivalent at 10 and 20 second delays. This does not seem to be the case. Differences in performance based on suffix type were not significant at 10 seconds--the largest difference between suffix types at this delay is only eight percentage points. In contrast, suffix type is clearly differentiated at 20 seconds, as was seen in Figure 2. Although delay was not a significant factor in the main analysis, a post hoc analysis of the 20-second delay data was run because an organized suffix effect at this delay was not expected and had not been demonstrated before, even with adult subjects.

The suffix effect was significant at the 20-second delay, $F(2,94) = 3.67$, $p = .03$. This effect was explored further through post hoc tests between means. While Balota and Duchek (in press) found no difference between same- and different-voice suffixes at this delay, in the current data there was a difference between same-voice (59% correct) and different-voice (64% correct) conditions. Nevertheless, a Bonferroni t-test indicated that this difference was not

significant. In contrast, the difference between same-voice and control suffixes was highly significant, $t(94) = 3.05$, $p < .01$.

If the final serial position for the 20-second data is considered alone, however, a large difference between all three suffix types is seen in the final serial position. Figure 4 illustrates the suffix curves for 20 seconds. A fanning of suffix type occurs in the terminal and preterminal serial positions. The difference between same- and different-voice suffixes is 9 percentage points, while the difference between different-voice and control conditions is 11 percentage points. The difference between tone and same-voice suffixes in the final serial position increases from 1 percentage point at 10 seconds to 20 percentage points at 20 seconds. These results are counter to those observed by Balota and Duchek for final serial position at 20 seconds. Their data indicated that the magnitude of the difference between tone and different-voice conditions was approximately equal at immediate and 20-second delays, and that the same- vs different-voice difference was eight times greater in the immediate than in the 20-second delay condition. In the current experiment, the trend is the opposite: as delay increases, the difference between suffix types increases. Again, this supports the notion that the effect of acoustic similarity of suffix becomes more differentiated as the retention

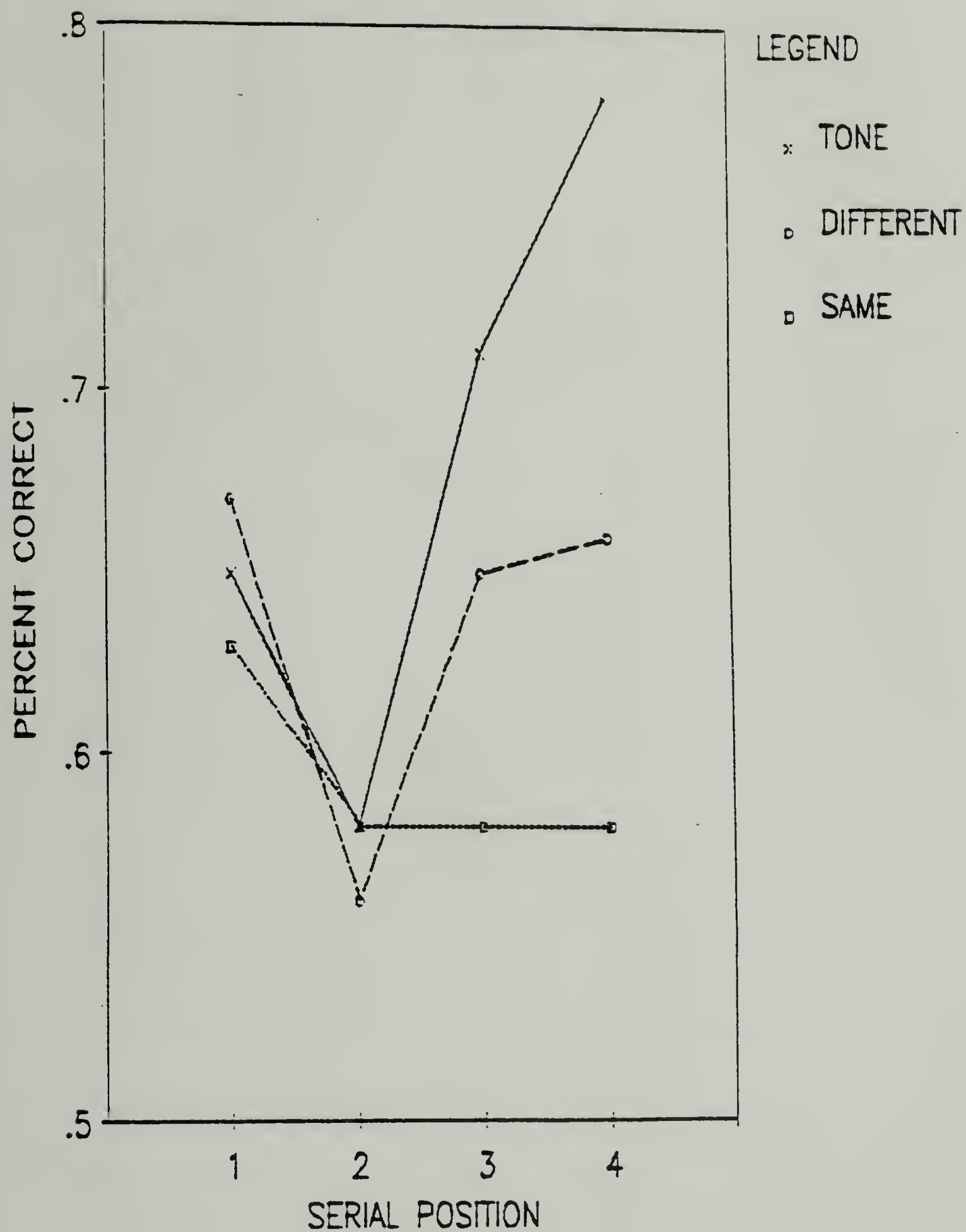


Figure 4. Mean percentage correct as a function of suffix and serial position at 20 seconds.

interval increases.

Serial position was a marginally significant factor in the main analysis, $F(3,141) = 2.57$, $p = .06$. Figure 5 shows the effect of suffix type across delay as a function of serial position. Since there was no silent control condition in this study, it is difficult to assess the impact of suffix on the serial position curve, which would be especially important when considering performance for the last serial position. These curves do not show a large drop in percent correct for the final serial position, but it should be noted that the typical serial position curve shows an advantage for the final serial position that is not evident here. Moreover, previous research using these stimuli without a suffix has yielded final serial position mean scores of 84% correct. The highest scores obtained here are for the tone suffix, and the final serial position for this condition is 71%. This seems to indicate all suffix conditions were effective in removing any recency effect normally seen in serial report memory tasks.

While the overall serial position effect was only marginally significant, it is useful to consider the phonological similarity dimension in terms of serial position. Phonological similarity was a highly significant factor in the main analysis, $F(1,47) = 15.04$, $p = .0003$. For all serial positions, performance on trials with phonologically similar foils was much worse than performance

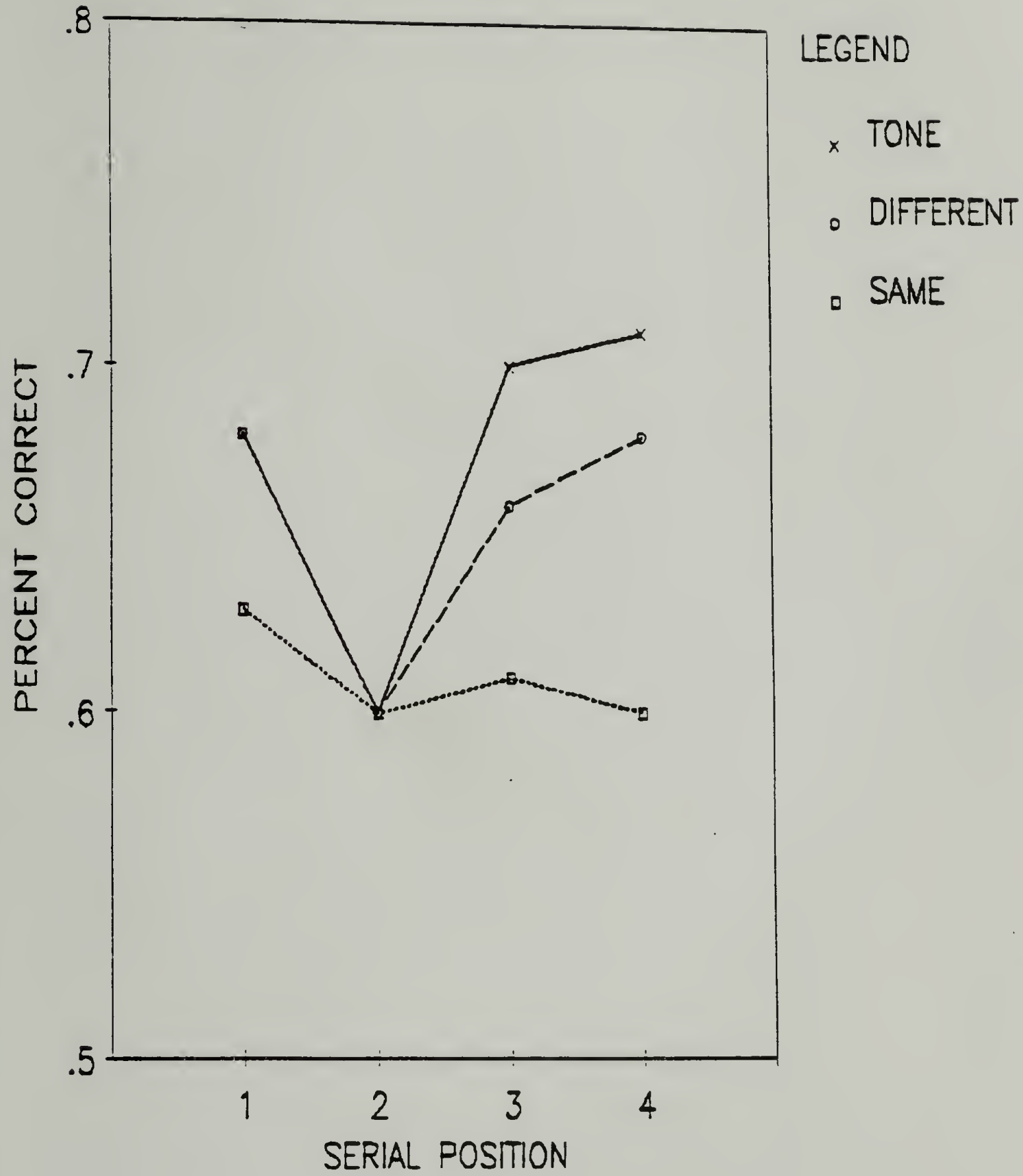


Figure 5. Mean percentage correct as a function of suffix and serial position across delay.

on trials with dissimilar foils, as illustrated in Figure 6. This finding is interesting in light of the apparently contradictory findings of Conrad (1971) and Hulme (1984). Both Conrad and Hulme used lists of words or pictures that rhymed with each other for their phonological similarity trials. Naturally, this provided opportunity for large numbers of errors on phonologically similar lists. Both authors concluded that preschool children were not sensitive to the phonological similarity of words. Although it may be argued that this task and the tasks of Conrad and Hulme are not comparable, the current task may even more conservative a test of sensitivity to phonological similarity than those of Conrad and Hulme. It is indeed remarkable that preschool children did not show any difference between phonologically similar and dissimilar lists in their studies and did in this study, where the only opportunity for confusion was with phonologically similar foils in the recognition set.

The interaction of phonological similarity with suffix type was another marginally significant factor in the main analysis, $F(2,94) = 2.43$, $p = .09$. In Figure 7, it can be seen that performance for same- and different-voice suffixes was more affected by changes in phonological similarity than was performance for the control condition. More specifically, mean percent correct for all three suffixes was lower for phonologically similar lists, but the means

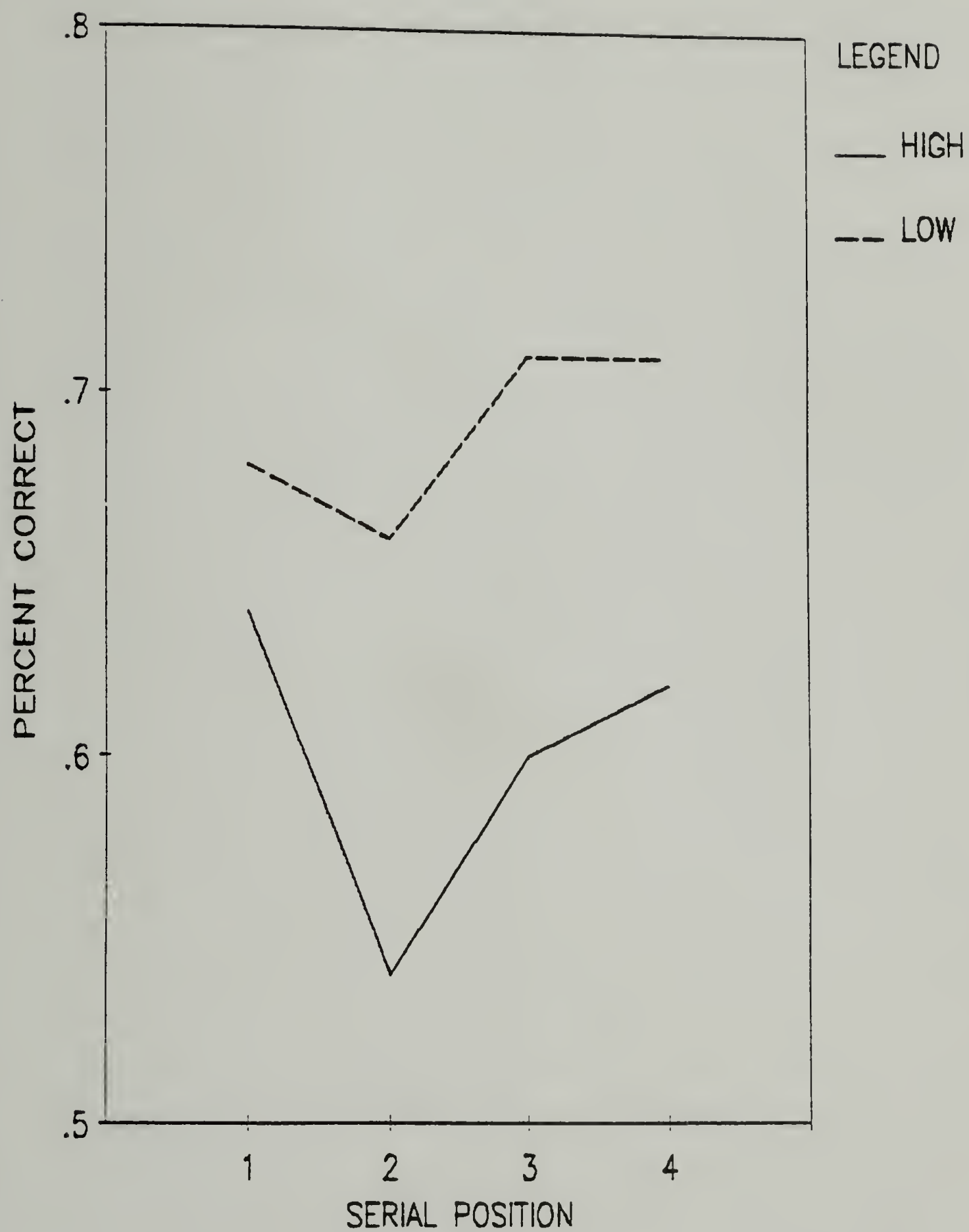


Figure 6. Mean percentage correct as a function of acoustic similarity of foils and serial position.

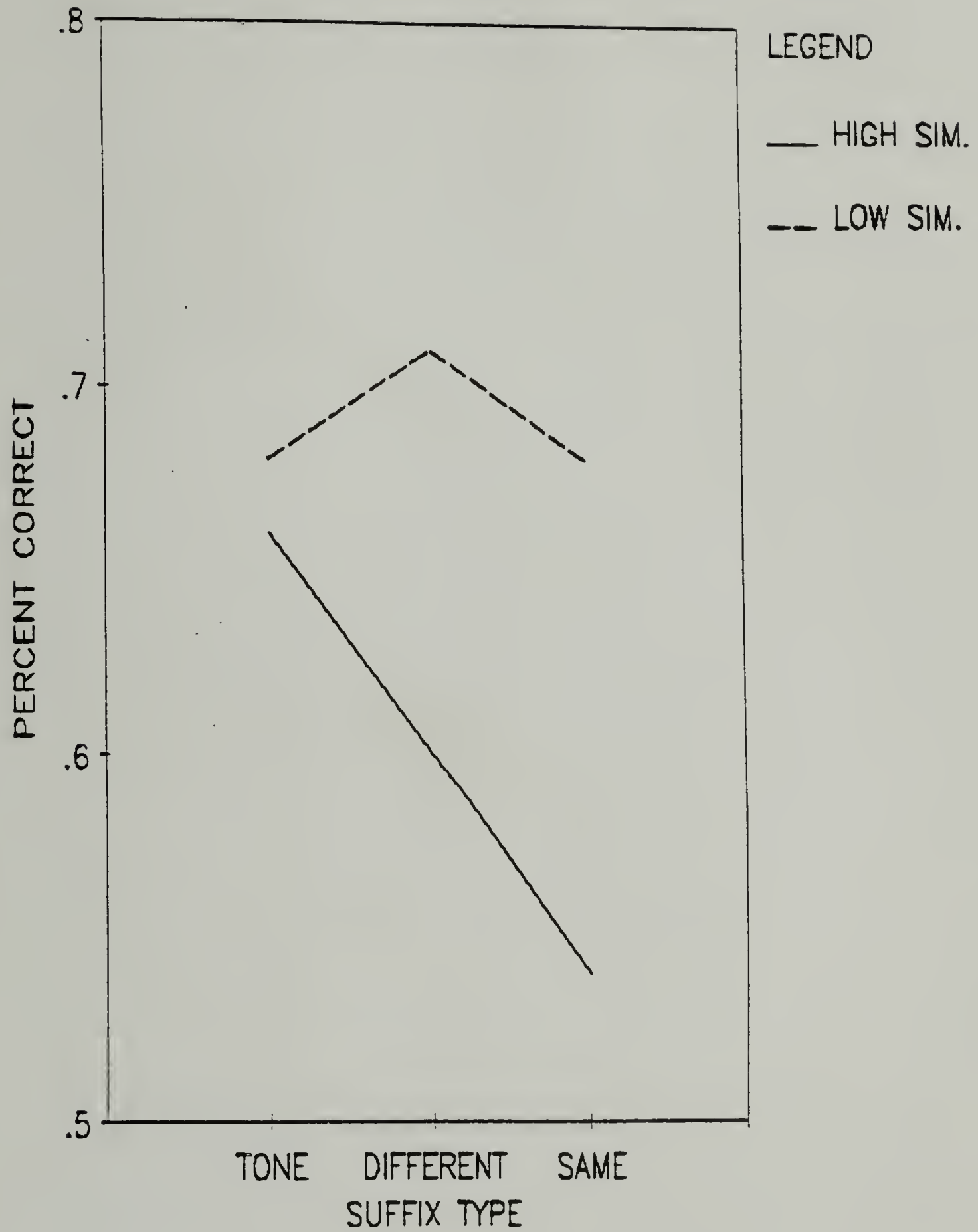


Figure 7. Mean percentage correct as a function of suffix type and acoustic similarity of foils.

for the voice suffixes were affected much more by the phonologically similar suffix than was the mean for the control. In fact, separate ANOVAs for phonologically similar and dissimilar lists revealed that the suffix effect was mainly accounted for by the trials with phonologically similar foils. Thus, lists with phonologically similar foils and acoustically similar suffixes cumulate to a large debilitating effect on memory.

CHAPTER IV

GENERAL DISCUSSION

This study has provided some interesting questions and possible interpretations for future consideration.

At the outset, one of the goals of this study was to investigate the duration of short-term auditory memory in preschoolers. The results suggest that the store is useful and available for report up to 20 seconds after list presentation. Although there was no baseline measure of memory immediately after list presentation, and despite the absence of a delay effect between 10 and 20 seconds, it seems obvious that some information is lost over the course of 20 seconds. Nonetheless, the remaining memory available is significantly above chance. Further, since children this age do not rehearse, there is no need to assume that such memory has been transformed into some suffix resistant memory through use of strategies. Any change would be the result of automatic processes, such as strength of association, and speed of activation. This long lasting store would be of great use for young children who, when learning to read complex sentences with new vocabulary, must hold information in memory until context makes a referent clear.

The implications of this finding for memory models are

interesting. First, it can be seen that, like adults' (Watkins and Todres, 1980), children's short-term auditory memory lasts as long as 20 seconds, or longer. This may indicate that there is little development in the temporal duration of the auditory short-term store. This interpretation would fit nicely with current research on development of short-term memory capacity (Case et al., 1980; Spring and Capps, 1974; Zhang & Simon, 1985). Together, these studies suggest the differences seen between adults and children on span tasks are not due to development of memory per se, but rather to development of vocalization speed. Second, since young children do not rehearse, it seems reasonable to assume that it is possible for an auditory trace to endure 20 seconds after list presentation and still be useful in aiding recall of auditorily presented information. If this is true for children, it seems logical that it would hold true for adults as well. Thus, the argument that rehearsal is responsible for all information retained for more than a few seconds after stimulus offset is considerably weakened. It is possible that auditory memory alone is not responsible for the utility of the memory trace available at 20 seconds; some other process might aid retrieval at some point during the delay. However, this data suggests that auditory memory indeed lasts for up to 20 seconds.

The sensitivity of children's auditory short-term memory to a suffix was also explored. In large part, this effect is confused by the paradoxical performance in the tone suffix condition, assumed to be a control condition. The lack of an overall recency effect for the tone trial in the main analysis and the absence of a large difference between tone and different-voice suffixes suggest that the tone may not actually serve as a control at this age. However, it is safe to say that children are affected by a suffix, as seen by the comparison of these results with previous data using this stimuli set (Cowan & Daly, manuscript in preparation). This provides evidence that is consonant with the Crowder and Morton (1969) PAS model of adult short-term auditory memory.

Another goal of this research was to evaluate the effect of acoustic similarity of a suffix on auditory memory. It may be argued that this experiment does not necessarily tap auditory short-term memory. This position would be considerably weakened if the speech suffixes were significantly different from each other, as seen in Morton, Crowder and Prussin (1971). While the pattern of results seems clear, the effect is not as powerful as in adult studies, especially when the suffixes are compared with each other. Again, the tone suffix is part of the problem. If the tone is not acting as a control for children this age, it is difficult to evaluate the sensitivity of children's

auditory memory to the acoustic similarity of a suffix item. The results seem to indicate that children's memory is not as dramatically affected by acoustic similarity of suffix as is the short-term auditory memory of adults. However, the pattern of results is the same for both groups: memory is most negatively affected by the same voice as list. Further, memory is more negatively affected by a different-voice suffix than it is by a tone suffix. Although, the Morton, Crowder and Prussin (1971) pattern of results are observed, information on how this sensitivity is affected by the passage of time is not available, since the delay effect was not significant and there was no interaction of delay and suffix. Thus, these findings are difficult to compare with those of Balota and Duchek (in press).

Finally, the effect of phonological similarity of items and foils on memory was addressed. This variable had a large effect on memory in this study, and may provide the strongest evidence that it is truly the auditory component of short-term memory that is being studied in this experiment. The results may indicate that auditory traces held for more than a few seconds lose some of their specific defining features, but retain their gross form, leading to more errors when very similar-sounding words are available as foils. Alternatively, the memory for an item might have fused with other items in memory, leading

to greater suggestibility when presented with a recognition set. For example, if a child received the list "Barn, Nurse, Door, Pie...Go," and the items fused in auditory memory, he may come up with the possibility of "Purse" as an answer. If there were a picture of a purse among the recognition set, he might be persuaded that the word was among the list items. While this experiment does not provide a clear interpretation of the phonological similarity effect, this is clearly an area that warrants further research. Hulme (1984) felt that the word similarity effect he observed in his experiment increased developmentally as a result of greater facility with rehearsal. These results would seem to contradict his interpretation, since a phonological similarity effect is seen in preschoolers, who do not rehearse yet.

In retrospect, this experiment has highlighted some of the frustrations of researching auditory memory in preschoolers. Although the results were not entirely paradoxical, they were difficult to interpret. The expected delay effect was not found, which interfered with the interpretation of the suffix effect. Since, prior to this study, the existence of a delayed suffix effect had not been demonstrated in preschoolers it became difficult to assess the suffix effect in absence of a delay effect. Nevertheless, some valuable methodological as well as theoretical implications for further research are suggested

by the findings as well as problems associated with this research.

First, methodological implications of this study suggest more stringent controls are necessary in order to gain meaningful information about children's auditory short-term memory and its properties. For example, the question of how to design a true control condition for suffix experiments must be addressed. The inclusion of a silent control as well as a tone control would most likely prevent the problems that arose in interpreting the results of this study. Second, in designing experiments to assess the duration of auditory memory, more delay lengths need to be sampled. In addition to including delays of several seconds, a no-delay (immediate) condition can help clarify results. For example, no delay effect was found in this study, which included a 10- and a 20-second delay. If the main effect of delay does not occur between 0 and 10 seconds, then the results of this study are highly suspect.

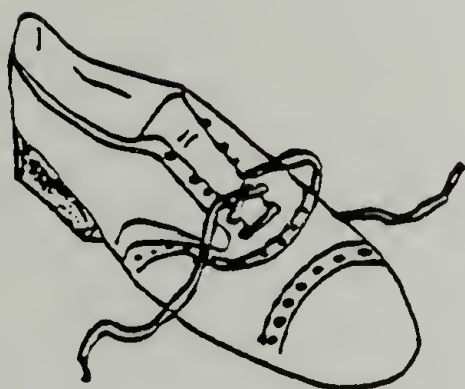
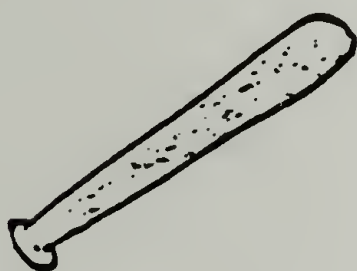
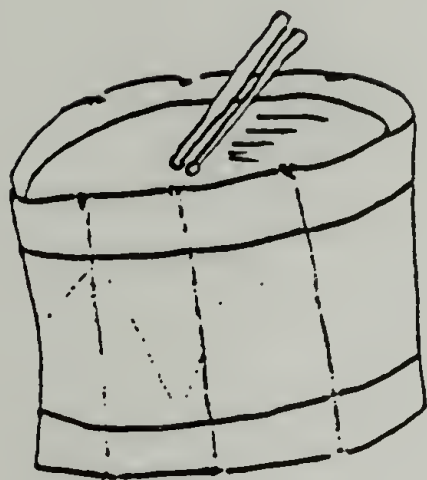
There are theoretical implications for future research that derive from this study. For example, the strength of the memory trace at various delays could be compared developmentally. In addition, hypotheses about what other processes could be aiding auditory memory at longer delays could be tested by manipulating the familiarity of items in the list. Moreover, this manipulation could be used for

both child and adult groups to provide another developmental comparison. The effect of phonological similarity on memory is another area that would benefit from further research. The two hypotheses mentioned as explanations in this chapter could be explored through the use of similar stimuli. If indeed the effect is found in children who don't rehearse, as seen in this experiment, then the cause of such an effect must be uncovered. It could provide valuable qualitative information about auditory short-term memory in children.

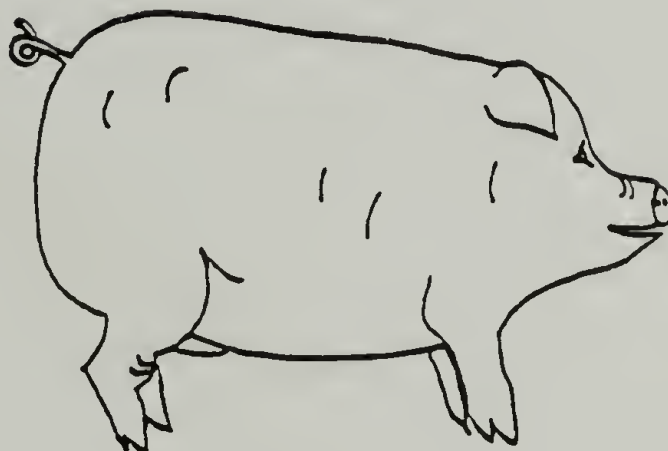
APPENDIX A

Sample picture stimuli

Sample of phonologically dissimilar picture sets

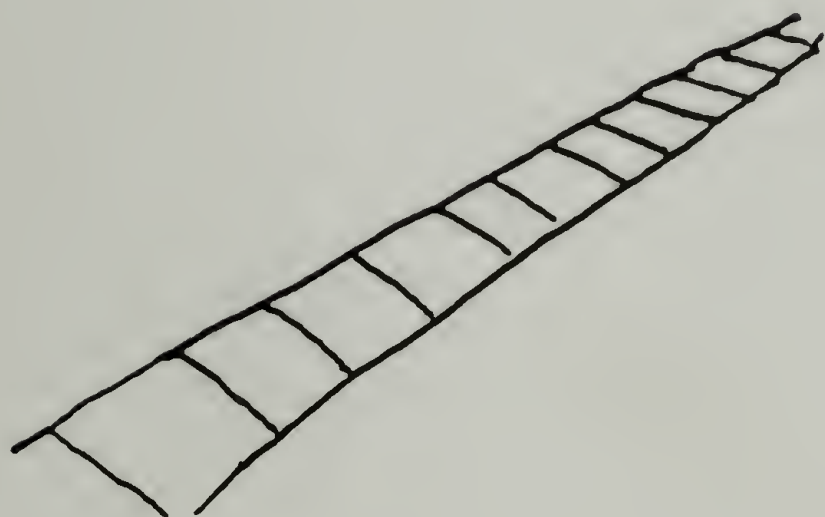


(top to bottom) drum, bat, shoe. Target item = shoe.



(top to bottom) rake, pig, belt. Target item = pig.

Sample of phonologically similar picture sets



(top to bottom) pail, track,
nail. Target item = pail.



(top to bottom) mouse, comb,
house. Target item = house.

Appendix B

Stimuli lists and foils

Stimuli lists and foils

<u>Phonological Similarity</u>	<u>List Items</u>	<u>Card Position</u>	<u>Picture Foil Items</u>
R	Ship	T	Lip, Coat
	Pail	T	Track, Tack
	String	B	Ring, Soap
	Phone	M	Block, Rock

N	Clown	M	Bell, Thumb
	Tent	B	Sock, Yard
	Brush	B	Doll, Sled
	Leaf	T	Glove, Bike

R	Eye	M	Rug, Bug
	Light	T	Stamp, Kite
	Gate	T	Dish, Fish
	Pole	T	Bowl, Chick

N	Yarn	M	Bear, Hole
	Skirt	B	Bread, Horse
	Eggs	M	Boy, Pipe
	Box	T	Watch, Girl

R	Home	B	Mouse, Comb
	Boot	M	Pear, Chair
	Frog	M	Log, Road
	Fire	B	Seal, Wheel

N	Barn	T	Tie, Cup
	Nurse	M	Clock, Bag
	Door	T	Swing, Glass
	Pie	B	Sun, Train

N	Dog	M	Bench, Man
	Plane	T	King, Smoke
	Net	M	Star, Witch
	Gum	B	Pot, Fence

R	Soap	T	String, Ring
	Bug	B	Rug, Eye
	Road	B	Log, Frog
	Dish	M	Gate, Fish

N	Knife	T	Worm, Shell
	Horn	T	Mug, Nest
	Bus	B	Web, Slide
	Sheep	M	Plant, Fork

R	Tack	B	Pail, Track
	Mouse	T	Comb, Home
	Rock	B	Block, Phone
	Coat	B	Ship, Lip
N	Pig	M	Rake, Belt
	Desk	T	Key, Bird
	Flag	M	Broom, Shirt
	Shoe	B	Drum, Bat
R	Stamp	M	Light, Kite
	Wheel	M	Seal, Fire
	Chick	B	Pole, Bowl
	Pear	T	Chair, Boot

Appendix C
Summary of Counterbalancing

Appendix C

Summary of Counterbalancing

<u>Subject #</u>	<u>order of Suffix Pres.</u>	<u>order of Probe Pres.</u>	<u>order of Delay Pres.</u>	<u>alternation Phonemic Similarity</u>
1 & 2	TSD	F - B	10-20	RNRNRN/NRNRNR
3 & 4	TSD	F - B	20-10	RNRNRN/NRNRNR
5 & 6	SDT	F - B	10-20	RNRNRN/NRNRNR
7 & 8	SDT	F - B	20-10	RNRNRN/NRNRNR
9 & 10	DTS	F - B	10-20	RNRNRN/NRNRNR
11 & 12	DTS	F - B	20-10	RNRNRN/NRNRNR
13 & 14	TSD	F - B	10-20	NRNRNR/RNRNRN
15 & 16	TSD	F - B	20-10	NRNRNR/RNRNRN
17 & 18	SDT	F - B	10-20	NRNRNR/RNRNRN
19 & 20	SDT	F - B	20-10	NRNRNR/RNRNRN
21 & 22	DTS	F - B	10-20	NRNRNR/RNRNRN
23 & 24	DTS	F - B	20-10	NRNRNR/RNRNRN
25 & 26	TSD	B - F	10-20	RNRNRN/NRNRNR
27 & 28	TSD	B - F	20-10	RNRNRN/NRNRNR
29 & 30	SDT	B - F	10-20	RNRNRN/NRNRNR
31 & 32	SDT	B - F	20-10	RNRNRN/NRNRNR
33 & 34	DTS	B - F	10-20	RNRNRN/NRNRNR
35 & 36	DTS	B - F	20-10	RNRNRN/NRNRNR
37 & 38	TSD	B - F	10-20	NRNRNR/RNRNRN
39 & 40	TSD	B - F	20-10	NRNRNR/RNRNRN
41 & 42	SDT	B - F	10-20	NRNRNR/RNRNRN
43 & 44	SDT	B - F	20-10	NRNRNR/RNRNRN
45 & 46	DTS	B - F	10-20	NRNRNR/RNRNRN
47 & 48	DTS	B - F	20-10	NRNRNR/RNRNRN

REFERENCES

- Alegria, J., & Pignot, E. (1979). Genetic aspects of verbal mediation in memory. Child Development, 50, 235-238.
- Baddeley, A. D. (1981). The concept of working memory: A view of its current state and probable future development. Cognition, 10, 17-23.
- Baker-Ward, L., Ornstein, P.A., Holden, D. J. (1984). The expression of memorization in early childhood. Journal of Experimental Psychology, 37(3), 555-575.
- Balota, D. A., & Duchek, J. M. (in press). Voice-specific information and the 20-Second delayed suffix effect. Journal of Experimental Psychology: Learning, Memory and Cognition.
- Bradley, L., & Bryant, P. E. (1983). Categorizing sounds and learning to read -- a causal connection. Nature, 301, 419-421.
- Conrad, R. (1971). The chronology of the development of covert speech in children. Developmental Psychology, 5, 398-405.
- Cowan, N. (1984). On short and long auditory stores. Psychological Bulletin, 96, 341-370.
- Cowan, N. & Kielbasa, L. A. (in press). Temporal properties of memory for speech in preschool children. Memory and Cognition.

- Crowder, R. G. (1969). Behavioral stages in immediate memory. Journal of Verbal Learning and Verbal Behavior, 8, 524-528.
- Crowder, R. G. (1971). The sound of vowels and consonants in immediate memory. Journal of Verbal Learning and Verbal Behavior, 10, 587-596.
- Crowder, R. G. (1976). Principles of learning and memory. Hillsdale, NJ: Erlbaum.
- Crowder, R. G. (1978). Mechanisms of auditory backward masking in the stimulus suffix effect. Psychological Review, 85, 502-524.
- Crowder, R. G. (1983). The purity of auditory memory. Philosophical Transactions of the Royal Society of London, B302, 251-265.
- Crowder, R. G., & Morton, J. (1969). Precategorical acoustic storage (PAS). Perception and Psychophysics, 5, 365-373.
- Dallet, K. (1965). "Primary memory:" The effects of redundancy upon digit repetition. Psychonomic Science, 3, 237-238.
- Darwin, C. J., Turvey, M. T., & Crowder, R. G. (1972). An auditory analogue of the Sperling partial report procedure: Evidence for brief auditory storage. Cognitive Psychology, 3, 258-267.
- Davis, S. M., & McCrosky, R. L. (1980). Auditory fusion

- in children. Child Development, 51, 75-80.
- Dempster, F. N. (1985). Short-term memory development in childhood and adolescence. In C. Brainerd & M. Pressley (Eds.) Basic processes in memory development. New York, NY: Springer-Verlag.
- Dempster, F. N., & Rohwer, W. D. (1983). Age differences and modality effects in immediate and final free recall. Child Development, 54, 30-41.
- Engle, R. W., Fidler, D. S., & Reynolds, L. H. (1981). Does echoic memory develop? Journal of Experimental Child Psychology, 32, 459-473.
- Frank, H. S., & Rabinovitch, M. S. (1974). Auditory short-term memory: Developmental changes in precategorical acoustic storage. Child Development, 45, 522-526.
- Flavell, J. M., Beach, D. R., & Chinsky, J. M. (1966). Spontaneous verbal rehearsal in a memory task as a function of age. Child Development, 37, 283-299.
- Greenberg, S. N., & Engle, R. W. (1983). Voice changes in the stimulus suffix effect: Are the effects structural or strategic? Memory and Cognition, 11, 551-556.
- Hulme, C. (1984). Developmental differences in the effects of acoustic similarity on memory span. Developmental Psychology, 20, 650-652.

Irwin, R. J., Ball, A. K. R., Kay, N., Stillman, J. A., & Rosser, J. (1985). The development of auditory temporal acuity in children. Child Development, 56, 614-620.

Kail, R., & Hagen, J. W. (1982). Memory in childhood. In B. B. Wolman (Ed.), Handbook of developmental psychology. Englewood Cliffs, NJ: Prentice Hall.

Kuczaj, S. A., II. (1979). Evidence of a language learning strategy: On the relative ease of acquisition of prefixes and suffixes. Child Development, 50, 1-13.

Liberman, I. Y., Shankweiler, D., Liberman, A. M., Fowler, C., & Fischer, F. W. (1977). Phonetic segmentation and recoding in the beginning reader. In A. S. Reber & D. Scarborough (Eds.) Toward a psychology of reading: The proceedings of the CUNY conference (pp. 207-225). Hillsdale, NJ: Erlbaum.

Massaro, D. W. (1972). Preperceptual images, processing time, and perceptual units in auditory perception. Psychological Review, 79, (2), 124-125.

Morais, J., Cary, L., Alegria, J., & Bertelson, P. (1979). Does awareness of speech as a sequence of phones arise spontaneously? Cognition, 7, 323-331.

Morton, J., Crowder, R. G., & Prussin, H. A. (1971). Experiments with the stimulus suffix effect.

- Journal of Experimental Psychology, 91, 169-190.
- Siegel, L. S., & Linder, B. A. (1984). Short-term memory processes in children with reading and arithmetic learning disabilities. Developmental Psychology, 20, 200-207.
- Tallal, P., Stark, R., Kallman, C. & Mellits, D. (1981). A reexamination of some nonverbal perceptual abilities of language-impaired and normal children as a function of age and sensory modality. Journal of Speech and Hearing Research, 24, 351-357.
- Treisman, A. (1964). Monitoring storage of irrelevant messages in selective attention. Journal of Verbal Learning and Verbal Behavior, 3, 449-459.
- Watkins, M. J., & Todres, A. K. (1980). Suffix effects manifest and concealed: Further evidence for a 20-second echo. Journal of Verbal Learning and Verbal Behavior, 19, 46-53.
- Watkins, O. C., & Watkins, M. J. (1980). The modality effect and echoic persistence. Journal of Experimental Psychology: General, 109, 251-278.

